Hidden Assumptions in Project Management Tools

By Dr. Eva Regnier

(The following is part one of a two-part column written by Dr. Regnier. The second part will be published in our next newsletter.)

Scheduling and managing the activities involved in completing a complex, large-scale project can be overwhelming. Many managers use project management software that is built on some basic models, but they are not familiar with the underlying models. In DRMI's resident courses, we introduce the tools that are commonly used in project management and integrated into project management software, as well as the key concepts and assumptions underlying them.

The Critical Path Method (CPM) is used to analyze the interdependencies among activities and identify the activities which require more attention and resources. The Program Evaluation Review Technique (PERT) was first developed by the U.S. Navy in the 1950s for the management of the Polaris missile project, as a means to model the uncertainty inherent in the scheduling of a complex project.

In DRMI's courses, we also discuss and illustrate the value of using simulation to relax some of the restrictive assumptions of PERT and to generate more reliable, though not necessarily definitive, probability distributions for the completion time and budget for an entire project.

These tools can generate detailed results, in particular a probability distribution for the overall project completion time. The results are appealing because they appear scientific. This can inspire users to make authoritative pronouncements such as, "There is a 95% chance that the project will be completed in 18 months." However, the results are misleadingly precise. The failure of many projects to be completed in the times predicted by the models can undermine managers' faith in the project management tools, in their teams or in their contractors. It is therefore important to understand the assumptions behind these uncertainty models and their results before using them to make commitments or set performance targets.

Outline of CPM and PERT

The first step in any CPM or PERT analysis is to identify the activities required to complete the project, and then to list their predecessor activities---for example, the simulator must be received before the installation can begin. Simply identifying activities and identifying their precedence relationships, sometimes in a Gantt chart, is very valuable because it clarifies the scope of the project, the activities that must be coordinated, and generally puts structure on what can at the outset seem an overwhelming muddle.

The next step is to map the activities and their dependencies in a network, representing each activity (either as a node or as an arc---see Moore and Weatherford Chapter 14 for more detail), with all the predecessors feeding in to each activity. Next, in both CPM and PERT, the time to complete each activity is estimated. To complete a simple CPM analysis, a point estimate of the completion time is sufficient.

These estimates are then used to identify the earliest possible completion time of the overall project, as well as the earliest and latest start time for each activity, and the slack, or amount of time by which the start and/or end time can be adjusted without affecting the completion time of the overall project. The critical path is the sequence of activities that have a zero slack time; in other words they must each start at their earliest possible start time and be completed in no more than the estimated time for the overall project to be completed on time.

In its simplest form, the PERT method involves determining three estimates of the time required to complete each activity---the optimistic, most likely, and pessimistic estimates. Together with a few assumptions, these estimates determine the probability distribution of the completion time

on the critical path. The key assumptions imply that the probability distribution of the completion time of the entire project can be derived by analyzing only activities on the critical path.

They are:
1. The critical path does not change;
2. The project completion time is a normally distributed random variable; and
3. The activity completion times are statistically independent will not be influenced by management intervention.

A further important assumption in PERT is that each activity's completion time is a random variable with a special distribution called the "PERT-beta" and based on the PERT-beta, the expected completion time and its variance for each project can be determined according to simple formulas. This assumption, and the issues involved in estimating the parameters for each activity will be addressed in a related article in the next DRMI newsletter.

The advantages of the basic PERT implementation are its simplicity and accessibility. The data required activities, predecessors, and optimistic, pessimistic, and most likely estimates for activity completion times are relatively easy to elicit from the knowledgeable people. The small and accessible data requirement is a major advantage and proposed improvements on PERT usually restrict the data requirement to three estimates per activity as well. This simplicity in PERT extends to the relevant calculations, which can be done quickly and even by hand, for complex networks once the critical path has been identified.

Assumption 1: The critical path does not change

The first assumption worthy of discussion is that the distribution of the completion time of the overall project can be determined by analyzing only the completion times of activities on the critical path. This implies that the expected time for the completion of the project is the sum of the expected completion times for the activities on the critical path. In addition, the variance of the completion times of the entire project is assumed to be the sum of the variances of completion times for the activities on the critical path.

Even if the distributions of the individual activity completion times were accurately modeled, this assumption can lead to bias. The reason is that the critical path identified based on the most likely or expected completion time will not necessarily end up being the critical path. For example, if an activity that has one week of slack starts more than a week late, a path that includes that activity may become critical, delaying the entire project.

This assumption biases the results of the simple PERT formulas in two ways. First, the expected time to complete the entire project will be underestimated. Second, the variability in the time to complete the project will also be underestimated. The reason for both underestimates is that scenarios in which another path takes longer than the identified critical path are ignored. Understating the expected completion time and the variance both contribute to underestimating the probability of late completion.

This is the effect of the PERT assumptions, not the fault of a manager, contractor, or employee. This effect is discussed in more detail in Schonberger (1981) and is also illustrated in DRMI's project management Flight Simulator case study. Schonberger also points out that the more variability there is in each activity's completion time, and the more paths there are in the network, the greater the bias.

Assumption 2: Project completion time is normally distributed

In the basic PERT implementation, it is assumed that the completion time for the entire project is a normally distributed random variable. A common justification for this assumption is the central limit theorem; see, for example, Moore and Weatherford. This theorem, which has many important applications, says that the sum of a large number of independent, identically distributed random variables will approximate a normally distributed random variable. Because the completion time for the critical path is the sum of random variables---the completion times of the critical path activities---it is argued that it can be approximated with a normal distribution.

However, activity completion times are not identically distributed, nor are they necessarily independent, as discussed later. Some activity completion-time distributions may have very

long tails, i.e. the pessimistic estimate is much higher than the optimistic and most likely estimates. Others may be symmetrical. In addition, the completion times often have different expected values---both long and short activities can occur in the critical path. The activities with the longest expected completion times will dominate the effects of shorter activities. In sum, when there are one or a few activities with much longer expected lead times than the others, or when one or a few of the activities have very long tails, the distribution of their sum will not have a normal shape.

The central limit theorem also refers to sums of a "large" number of random variables; large is often defined as greater than 30, and always at least 20. Because of the violations of the independence and identical-distribution assumptions in the activity completion times, the number of activities would have to be even larger for the sum of completion times to approximate a normal distribution. Even if the number of activities on the critical path is very large, a small number of very long activities or activities with very long tails can still distort the distribution and violate the normality assumption.

Assumption 3: Activity completion times are statistically independent

A third assumption of the PERT method is that activity completion times, while random, are independent of each other. The independence assumption means for example, that if we learn it takes longer than expected to receive one simulator, this does not give us any information about how long it will take to receive the second simulator.

This assumption is not necessarily realistic, as departures from the expected activity time for several activities can arise from the same underlying cause, such as a slow supplier or an overlooked requirement. This would imply that the activities times are positively correlated with each other. On the other hand, management intervention, such as reallocating resources from one activity to another, could cause two activity times to be negatively correlated. One is completed faster than expected because the resources are diverted from a second activity, which therefore takes longer than expected.

Either way, because the activities are related, it is unlikely that they are uncorrelated. If activity completion times are positively correlated, then assuming they are independent, as is commonly done, causes a bias to underestimate both the expected completion time and the variance of the completion time of the overall project. As discussed above, both of these biases will contribute to underestimating the probability of very long completion times.

The independence assumption is built into PERT and often this assumption is applied in network simulation as well, causing the same kind of bias. Some project management software and some simulation software (including Crystal Ball) do allow for building in correlations among the activities. However, estimating reasonable values for the correlation between activity times is difficult for two reasons. First, the number of correlation coefficients that must to be estimated is a geometric function of the number of activities n(n 1) coefficients are required for n activities and may therefore be prohibitive in practice. Second, correlation coefficients are more difficult for experts to estimate than completion time parameters. Correlations are less intuitive and less familiar even to experts, because the completion time for an activity is eventually observed, whereas correlations are never directly observed.

A further assumption that remains when using simulation to estimate overall project completion time is that the activity completion times are exogenous, that is, they will not be influenced by any other activity completion time (as discussed above) nor will they be influenced by managers. The assumption that each activity completion time is distributed according to the specified beta implies that all the uncertainty is incorporated in that random variable, and none is determined by further intervention of the managers.

However, one of the most valuable aspects of modeling the network of precedences and estimating activity completion times is that it allows managers to identify the critical path, potential critical paths, and activities that can add or lose resources: essentially, ways to influence the activity completion time. Once managers begin to lean on critical activities, reallocate resources and otherwise intervene, they violate the assumption that the activities are distributed according to the specified betas.

Take-home insights

Much of the value in project management tools including PERT and CPM and more sophisticated project management software comes from simply estimating activity times and highlighting important dependencies. This helps managers identify places to allocate resources and attention to speed activities and improve coordination.

The bulk of the value in uncertainty models, including both PERT and simulation, comes from raising awareness of the effect of uncertainty, and in giving a rough approximation of the uncertainty in the final completion time. The effects of uncertainty and of the assumptions described here are not balanced on the positive and negative side; rather, uncertainty in activity completion times generally leads to delaying the final project. The quantitative output---particularly the probability distribution of the total completion time---should be viewed skeptically. Users should be aware that because of the simplifying assumptions they will tend to underestimate the probability of long project completion times.

References
Keefer, D.L. & W.A. Verdini, 1993. Better Estimation of PERT Activity Time Parameters. Management Science, 39(9), 1086-1091.
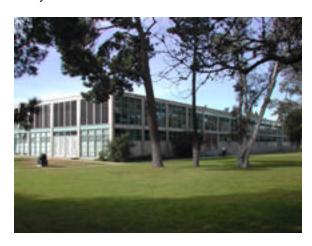
Moore, J. H. & L. Weatherford, 2001. Decision Modeling with Microsoft Excel (6th ed.). Prentice Hall. Chapter 14.

Schonberger, R.J. 1981. Why Projects are "Always" Late: A Rationale Based on Manual Simulation of a PERT/CPM Network. Interfaces 11(5), 66-70.

DRMI Activities

We've moved! Or at least most of us have. As you probably know from previous newsletters, the west wing of Herrmann Hall will undergo renovation starting in March, requiring DRMI to find a new home. The move to our new home in Halligan Hall began at the end of November, and all but four faculty and two staff members are now located in our new spaces. The remaining faculty and staff will join us the first week in February. While we were all sad to leave our long-time home, we are pleased with

our new facilities, which were renovated prior to our moving. As you can imagine, there were many details to work out before we could teach

in our new facilities. After much feverish activity to prepare, DRMC 05-1 successfully began on 10 January. For those of you who want to contact us, our email addresses and phone numbers remain the same. Our new mailing address is: Defense Resources Management Institute, 699 Dyer Rd., Room M-5, Naval Postgraduate School, Monterey, CA 93943.

On November 19, 2004, Dr. Raymond Gilpin, Academic Chair for Defense Economics at the Africa Center for Strategic Studies, visited DRMI as part of a larger two day visit to SIGS in order to foster closer relationships between NPS and the Africa Center, one of five regional DoD schools. Professor Peter Frederiksen coordinated his visit to DRMI. He was welcomed by Professor Kent Wall and then made a short presentation to DRMI faculty on the Africa Center and its programs. DRMI presentations were made by Associate Professor Angelis, and Senior Lecturers Don Bonsper, Al Polley and Steve Hurst. Among the topics requested to be covered were the content and objectives of DRMI courses, the syllabus development process, feedback mechanisms, developing countries experience with mobile courses, and the possibilities for long distance learning.

Professor Jim Blandin and Senior Lecturer Don Bonsper taught in the International Defense Acquisition Resource Management (IDARM) program in November. There were 17 participants from nine countries.

DRMI held its third course for Bosnia and Herzegovina (BiH) in Sarajevo, 2-12 November.

BiH is integrating the defense planning and security responsibilities of its two entities

(Federation of Bosniacs and Croats; Republica Srpska) at the State level. The course included participants from the BiH MoD, Joint Staff and Operational Command, as well as from both entities. Key participants included the BiH MoD Director of the Sector for Finance and Budget, the BiH Joint Staff Deputy Chief for Resources, and the BiH Operational Command Deputy Commander for Support.

The current situation in BiH is analogous to the U.S. system prior to development of the PPBS. The entities have been making resource allocation decisions with little regard for State objectives and priorities, much as in the pre-PPBS US, when three military departments made resource allocation decisions with little regard for overall DoD objectives and priorities. Students of the history of US PPBS development will be familiar with the integration challenges BiH faces. However, BiH has an additional challenge--many outside agencies (UN, OSCE, NATO, IMF, to name a few) have put limits on their sovereignty to make defense policy and resource allocation decisions. The participants agreed this was necessary due to their recent history.

Faculty Research and Conference Presentations

Assistant Professor Jim Airola will chair a session on monetary policy at the upcoming Western Economic Association International Pacific Rim Conference at Lingnan University, Hong Kong. He will also present his paper titled "Trade and Wages:

A Regional Analysis of the Effects of Trade on Wages in Mexico," which explores the distributional effects of the NAFTA for workers on both sides of the border.

Professor Jim Blandin published a case study titled, "Homeland Security", in a new book this month (January 2005): <u>Terrorism and Peacekeeping: New Security Challenges</u>, Volker Franke (Ed.), Westport, CT: Praeger.

John Enns, PhD, attended the Navy's Human Capital Strategy (HCS) conference in Charlottesville, VA (Dec 7-9). After an introduction to the topic by CNO Clark the conference broke into four working groups, comprised of the attendees including all forms of Navy manpower analysts and managers, to focus on barriers that prevent desired human resource outcomes. A task force is being formed to provide a strategy document by June to guide Navy efforts in developing new human resource policies to overcome these barriers. NPS will play a role in supporting the task force in areas such as cost analysis, manpower modeling and compensation policy.

At the request of NATO Headquarters in Brussels, Francois Melese, PhD, prepared two talks related to public management and budgeting that were delivered by a panel of NATO experts invited by the Ukraine. Although unable to join the team to represent the U.S. in person this year, Francois was invited to participate in the next set of meetings to be held in 2005. The talks were presented by the panel on November 10-11, just before the recently contested second round of the presidential elections. The first talk was delivered at a training course held at the Ukrainian Ministry of Defense in Kyiv, and the second at a Joint NATO-Ukraine Working Group meeting with the Economics Ministry.

Robert McNab, PhD, presented the following paper at the 60th Annual Conference of the International Institute of Public Finance in Milan in August: Azre, J., J. Martinez-Vazquez, and R. McNab (2004). Does Decentralization Influence the Composition of Public Expenditures? He also presented the following paper at the 2nd Annual Conference on Genocide at California State University, Sacramento in October: McNab, R. and Mohamed, A.L. (2004). Human Capital, Natural Resource Scarcity, and the Rwandan Genocide.

Under review. "Autopsy of Genocide: New Patterns, Paradigms and Prognosis. He discussed the following paper at the 97th Annual meetings of the National Tax Association in Minneapolis in November: The German Reunification Revisited: A Tax-Cultural Perspective-Birger Nerré and Carsten Pallas, University of Hamburg

Natalie Webb, PhD, presented "The Role of Occupational, Professional, and Industry Norms on Individual Giving", at the annual Association of Research on Voluntary Organizations and Nonprofit Action in Los Angeles, November 2004.

Rikki Abzug (The New School University) and Natalie Webb received funding to extend their preliminary analysis of occupation, profession, and industry on charitable giving. Their research grant was awarded for the calendar year, 2005.

Curriculum Developments, Teaching News, and Faculty/Staff Service

McNab, R. and K. Bailey have submitted an article entitled 'Environmental Security in Latin America" to the Journal of Conflict Analysis. Dr McNab also graduated the following NPS thesis students:
Ms. Yee Ling Ang
Captain Joseph Katz

Lt. Janet Days
1st Lt. Melissa Simmons
Captain John Wilkerson

Associate Professor Natalie Webb taught a four-hour business planning workshop at the Navy Corporate Business Course at the University of North Carolina in October. The course, sponsored by the Executive Learning Officer of the Navy, and taught by UNC, Berkeley, and NPS faculty, was offered to 35 Navy captains, senior enlisted, and GS-15s.

Contrary to what you may have heard or read elsewhere, Al Polley is NOT leaving DRMI! He was selected by the Department of the Navy, the Defense Security and Cooperation Agency, and Tufts University to be one of nineteen participants in the Global Masters of Arts Program, a one-year International Affairs graduate studies program for mid-career professionals involved with international security cooperation. The program is taught by Tufts University's Fletcher School of Law and Diplomacy and combines three two-week residency sessions with internet-based courses. Specific courses are Transnational Social Issues, Security Studies, International Organizations, Leadership and Management, International Negotiation, International Trade Economics and Investment, International Finance, and International Politics. Al will continue to teach at DRMI during the course.

Publications

Everhart, S., J. Martinez-Vazquez, and R. McNab (2004). Corruption, Investment, and Growth. National Tax Association Proceedings: Ninety-Sixth Annual Conference 2003, 84-90.

A Solemn Goodbye

A former member of our faculty, David Rose, PhD, died at the age of 46 of lung cancer on December 11, 2004. The following tribute was written by Professor Kent Wall:

David will be missed very much. He was hired in 1994, following our hiring of Jim Felli (who is now working at Eli Lilly). They knew one another while graduate students at SUNY Buffalo and I think it was this connection that brought David to our attention at DRMI. David did not spend a long enough time with us - that is how I view it.

David gave one of the best presentations for his job interview that I have ever heard - and that was just the beginning. He was truly gifted when it came to understanding the mission of DRMI and the nature of our participants. His lectures were as near to perfect as I could tell. He always had the content perfected. He always delivered them in a most disarming fashion. But the most amazing thing about him was his uncanny sense of how to compose the lecture - what details to include and what details to gloss over - what concepts to emphasize and what concepts to tread upon lightly. He thoroughly understood the purpose of each lecture in the "big picture" of each course, and then because of this, spun a story with the lecture that perfectly fit our purposes. He was amazing.

I quickly learned that the best way to improve one of my lectures was to give the package to David, assign him the lecture and then witness how he morphed it. I was never disappointed! For those of you new to DRMI, you may recall the introductory lecture for the "Logistics Week" in the IDMC. I've had responsibility for that lecture going way back to the mid-80's - I put all the elements in there that are now in the lecture - BUT, the beautiful story that serves to introduce it all - and tie it together in a plausible Drmecia scenario - that was ALL David. Somehow he never failed to do that -- take the bare bones of a lecture and flesh it out -- transform it -- into something that left everyone saying "… why didn't I think of that…"

David, we will always remember you, and we will always feel the loss.

Participant News

Previously stationed at USAREUR HQ in Germany, Larry Acquaviva, a participant in DRMC 04-1, was recently assigned to Eighth United States Army, Office of the Assistant Chief of Staff for Resource Management in Seoul Korea. He is working in Program and Budget Division in capacity of Chief, Budget Execution branch and is responsible for the budget execution of this MACOM and its major subordinate commands throughout South Korea.

In an email, we received the following:

My Dear Friends,
Thank you very much [for your newsletter greetings]! I am already assigned as a MILREP at the Bulgarian Delegation to NATO, Brussels. My e-mail is the same.
Wish to all of you success and luck.
Radm. Emil Lyutskanov

DRMI Course Catalog and Brochure

The 2005 course catalog and the Defense Resources Management Course brochure will soon be available. If you would like copies, please contact the Admin Office at 831-656-2104 (DSN 756) or send e-mail to DrmiAdmin@nps.navy.mil

Future Resident Courses

Defense Resources Management Course (four-week DRMC):

DRMC 05-2	25 Apr - 18 May 2005
DRMC 05-3	23 May - 17 Jun 2005
DRMC 05-4	25 Jul - 18 Aug 2005
DRMC 05-5	22 Aug - 16 Sep 2005

Please contact Sue Dooley at (831) 656-2104 or DrmiAdmin@nps.navy.mil for quota and enrollment information.

International Defense Management Course (eleven-week IDMC):

IDMC 05-1	7 Feb - 20 Apr 2005
IDMC 05-1	26 Sep - 9 Dec 2005

36th annual Senior International Defense Management Course (four-week SIDMC)

SIDMC 2005   27 Jun - 22 Jul 2005

For additional information on any of our resident courses please contact Sue Dooley at (831) 656-2104 or e-mail DrmiAdmin@nps.navy.mil

Defense Resources Management Institute

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